Prefer Oral Presentation, Microwave Oscillators

STABILITY AND PHASE NOISE TESTS OF TWO CRYO-COOLED SAPPHIRE OSCILLATORS

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A cryocooled Compensated Sapphire Oscillator (CSO), developed for the Cassini Ka-band Radio Science experiment, and operating in the 8K – 10K temperature range was previously demonstrated to show ultra-high stability of $\sigma_y = 2.5\times10^{-15}$ for measuring times 200 seconds $\leq \tau \leq$ 600 seconds using a hydrogen maser as reference [1]. We present here test results for a second unit which allows CSO short-term stability and phase noise to be measured for the first time. Also included are design details of a new RF receiver and an intercomparison with the first CSO unit.

Cryogenic oscillators operating below about 10K offer the highest possible short term stability of any frequency sources. However, their use has so far been restricted to research environments due to the limited operating periods associated with liquid helium consumption. The cryocooled CSO is being built in support of the Cassini Ka-band Radio Science experiment and is designed to operate continuously for periods of a year or more. Performance targets are a stability of $3\text{-}4\times10^{-15}$ (1 second $\leq \tau \leq$ 100 seconds) and phase noise of -73dB/Hz @ 1Hz measured at 34 GHz. Installation in 5 stations of NASA's deep space network (DSN) is planned in the years 2000 - 2002.

In the previous tests, actual stability of the CSO for measuring times $\tau \leq$ 200 seconds could not be directly measured, being masked by short-term fluctuations of the H-maser reference. Excellent short-term performance, however, could be inferred by the success of an application of the CSO as local oscillator (L.O.) to the JPL LITS passive atomic standard, where medium-term stability showed no degradation due to L.O. instabilities at a level of $\sigma_y = 3\times10^{-14}/\sqrt{\tau}$. A second CSO has now been constructed, and all cryogenic aspects have been verified, including a resonator turn-over temperature of 7.907 K, and Q of 7.4×10^{8}. These values compare to a turn-over of 8.821 K and Q of 1.0×10^{9} for the first resonator. Operation of this second unit provides a capability to directly verify for the first time the short-term (1 second $\leq \tau \leq$ 200 seconds) stability and the phase noise of the CSO units.

The RF receiver used in earlier tests was sufficient to meet Cassini requirements for $\tau \geq 10$ seconds but had short-term stability limited to $2\text{-}4\times10^{-14}$ at $\tau = 1$ second, a value 10 times too high to meet our requirements. A new low-noise receiver has been designed to provide $\approx10^{-15}$ performance at 1 second, and one receiver is now operational, demonstrating again short-term CSO performance with H maser-limited stability. Short-term performance was degraded in the old receiver due to insufficient tuning bandwidth in a 100MHz quartz VCO that was frequency-locked to the cryogenic sapphire resonator. The new receivers are designed for sufficient bandwidth, loop gain and low noise to achieve the required performance.

Reference

1. G. J. Dick and R. T. Wang, "Cryo-cooled Sapphire Oscillator with Ultra-High Stability," *Proc. 1998 International IEEE Frequency Control Symposium*, 528-533 (1998).

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